NSWC/WOL TR 78-26

A SOURCE MANUAL FOR INFORMATION ON NITINOL AND NiTi

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RESEARCH AND TECHNOLOGY DEPARTMENT

13 FEBRUARY 1978

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NAVAL SURFACE WEAPONS CENTER

Dahlgren, Virginia 22448 • Silver Spring, Maryland 20910

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NSWC/WOL/TR-78-26	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Source Manual for Information on NITINOL and NiTi		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David Goldstein		8. CONTRACT OR GRANT NUMBER(s) 12 33p.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Surface Weapons Center White Oak, Silver Spring, MD 20910		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS OPN; NSWC-1936/SEA-03542;
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 13 Feb 1978 13. NUMBER OF PAGES 32
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

NITINOL Nickel-Titanium Alloys
NiTi
Shape Memory Effect
Heat Engines

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This manual is a current listing of most of the published literature on NITINOL and NiTi alloys. It includes a bibliography, titles of a group of NSWC unpublished internal reports and patents issued. Guidelines for obtaining licenses for Navy-owned patents and for technical assistance by the Navy are presented.

The manual is intended to aid scientists and designers in locating specific kinds of information on NITINOL shape memory effect alloys.

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S/N 0102-LF-014-6601

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SUMMARY

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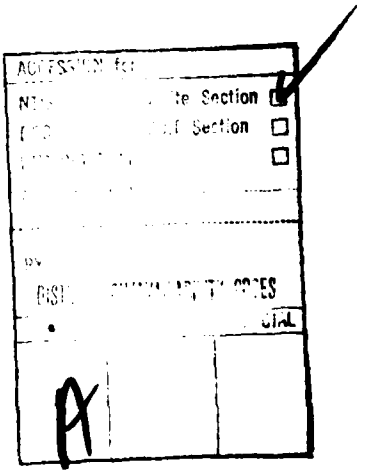

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1. INTRODUCTION

NITINOL is the generic name which has been given to the family of alloys which are near NiTi in composition. They were developed in 1961 during an examination of ten different intermetallic compounds considered potentially useful as missile nose tip materials. The NiTi alloy exhibited what is now identified as a "shape memory effect" (SME).

The inventors of record, (Patent 3 174 851) W. J. Buhler and R. Wiley named the alloy family "NITINOL". This is derived from the chemical symbol "NiTi" followed by "NOL", the acronym for Naval Ordnance Laboratory, the prior designation of the Naval Surface Weapons Center.

As knowledge of the existence of this shape memory effect alloy broadens, so does the demand for knowledge of its properties. To assist those now entering the NITINOL technology community this source manual has been prepared.

The early years of research in this alloy concentrated on an understanding of the mechanism of the transformation and a comprehension of the overt SME behavior of the alloy. This was followed by commercial production of the alloy and the appearance of a narrow line of commercial products using the alloy. Simultaneously a large number of patents and ingenious new ways to utilize the alloy surfaced, but only a few were commerciallized.

Among the difficulties would-be entrepreneurs encountered were a lack of adequate NITINOL supplies in the shape and sizes desired, of selected transition-temperature and transition band widths at reasonable costs, and with prompt delivery. It has become clear that it is now in the Navy's interest to assist in the development of commercial applications for NITINOL. These will ultimately provide a self sustaining production base for alloy, as well as provide commercial sources of metal for low volume DOD applications.

It is against this background that the NITINOL Technology Center was activated in 1977 to explore low cost manufacturing technology for NITINOL and to assist in the development of NITINOL-using devices. The Center has a complete melting and fabricating facility for NITINOL.

For the development of NITINOL-using devices, the Technology Center offers guidance and/or prototype development programs. These

are usually joint efforts with other government agencies or commercial organizations. (Funding by the private sector for materials and/or services is permitted on a non-profit basis. Advance payment to the Commander, Naval Surface Weapons Center is required.) The facilities of NSWC are available to the NITINOL Technology Center, enabling complete design and fabrication of prototypes. This service is offered only if equivalent capability is not available from industry and is subordinate to Navy projects.

Current programs include the fabrication of tubes of various sizes, wall thicknesses, and transition temperatures for specific Navy applications. Other DOD applications include special couplings for tubes and shafts. NITINOL wire and appropriate guidance are supplied on a continuing basis to universities for dental and bio-medical research. Cooperative programs have been instituted with NASA for outer space magnetometer positioners, and with DOT for overheated-journal-bearing detectors for rail cars. Heat engine technology, using NITINOL as the "working" element, appears promising for energy conservation applications.

2. LITERATURE SURVEY

Most of the publications listed here are available in open literature. Those with asterisks* following an identifier number may be ordered from the

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

NTIS also offers "Published Searches" of technical literature for $25 and "On Line" search for $100.

The NITINOL Technology Center maintains as complete a file of publications as possible. Duplication of specific articles can be arranged. Requests for assistance should be directed to:

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White Oak, Maryland 20910

Articles in the following bibliography are coded by the last two digits of the publication year, followed by the first letter of the principal author's name and a sequential number.

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3. INTERNAL REPORTS

The following reports are for internal distribution only. They are presented only to make known that some technical information has been developed on titled subject.

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4. PATENTS

Copies of patents may be obtained from the

U.S. Patent Office
U.S. Dept. of Commerce
Box 9
Washington D.C. 20231

The cost of patents is 50 cents each. Patents which are Navy owned (including the basic patent on NITINOL) may be licensed. The

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The Department of the Navy has instituted a program to license for commercial purposes patents and patent applications owned by the United States Government and in the custody of the Navy. This program is necessary because making, using or selling an invention covered by a Navy patent without express permission by the Government constitutes an unauthorized use. The Department of the Navy is presently implementing the Presidential Statement of Government Patent Policy of August 23, 1971.

A major premise of the Presidential Statement of Government Patent Policy, August 23, 1971 (36 FR 16887, August 26, 1971), is that Government inventions normally will best serve the public interest when they are developed to the point of practical application and made available to the public in the shortest possible time. The granting of express nonexclusive or exclusive licenses for the practice of these inventions may assist in the accomplishment of the national objective to achieve a dynamic and efficient economy.

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An applicant for a license should identify the patent or patent application number(s), state whether he is applying for a nonexclusive or an exclusive license, supply the name and address of the individual, organization or corporation (including the state of incorporation) applying for the license, provide a statement of the nature and type of the applicant's business and a statement of the purpose for which a license is desired along with a brief description of the applicant's plan to achieve that purpose including some indication of how the grant of a license would be in the public interest. Any other pertinent information should be included.

An applicant for an exclusive license should, in addition to the information set forth in the above paragraph, indicate whether or not he is a United States citizen, identify any other exclusive licenses he has ever had under patents or patent applications belonging to the U. S. Government, state to the best of his knowledge the extent to which the Government invention is being practiced by private industry, provide a statement of his capability to undertake the development and marketing required to achieve the practical application of the invention in a specified geographical area and field of use, provide a statement describing the time expenditure and other acts which he considers necessary to achieve practical application of the invention and include his offer to invest that sum to perform such acts if the license is granted. It would be beneficial for him to state why it will be in the public interest for him to have an exclusive license rather than a nonexclusive license.

An exclusive license may be granted after publication of the invention for nonexclusive licensing and after publication of the name of the selected applicant for a particular exclusive license if there is no responsible applicant for a nonexclusive license.

Exclusive licenses shall be subjected to several reservations of rights, as for example, an irrevocable royalty-free reservation throughout the world of rights in the invention to the United States Government. Exclusive licenses will contain a provision for royalty payments and/or other consideration flowing to the U. S. Government and in certain instances the granting of sublicenses to responsible applicants may be required of the exclusive licensee. Exclusive licenses will contain all terms and conditions which are required by law and by U. S. Government regulations and some additional provisions.

The information for applicants to submit in connection with requesting a license and the license provisions set forth in this paper are only intended to be illustrative and suggestive of the type of information needed and the possible kinds of provisions which may appear in a license. They are not intended to be limiting in content, meaning or words.

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Patent No. 3,174,851
"Nickel-Base Alloys"
W. Buehler and R. Wiley, Assignors to U.S.A.
Filed 1 Dec 1961
Issued 28 Mar 1965
3 Claims (Cl. 75-170)

Patent No. 3,285,470
"Thermally Actuated Devices"
E. H. Frei, S. Leibinzohn and Shtrikman
15 Nov 1966

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A. G. Rozner and W. J. Buehler, Assignors to U.S.A.
Filed 28 Aug 1965
Issued 7 Nov 1967
10 Claims (Cl. 75-170)

Patent No. 3,352,650
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Filed 19 Jul 1965
Issued 14 Nov 1967
12 Claims (Cl. 29-191)

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F. E. Wang, A. M. Syeles, W. L. Clark and W. J. Buehler,
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Filed 27 Jul 1965
Issued 14 Nov 1967
8 Claims (Cl. 148-1.6)

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9 Jul 1968

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Filed 5 Apr 1966
Issued 24 Sep 1968
10 Claims (Cl. 337-393)

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Filed 22 Nov 1965
Issued 17 Dec 1968
9 Claims (Cl. 72-47)

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Filed 11 Jul 1966
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12 Claims (Cl. 116-114.5)

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R. G. de Lange, C. A. Verbraak and J. A. Zijderveld, Assignors to Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek ten behoeve van Nijverheid, Corp. of the Netherlands
Filed 4 Feb 1966
Issued 17 Jun 1969
3 Claims (Cl. 244-1)

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C. C. Percy, Assignor to W. M. Chase Co.
Filed 11 Jul 1967
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2 Claims (Cl. 219-512)

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N. E. Rogen and R. J. Hill, Assignors to Avco Corp.
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20 Claims (Cl. 73-339)

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5 Claims (Cl. 73-362.8)

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Filed 2 May 1967
Issued 30 Dec 1969
3 Claims (Cl. 335-146)

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W. J. Buehler, Assignor to U.S.A.
Filed 7 Oct 1965
Issued 28 Apr 1970
8 Claims (Cl. 75-135)

Patent No. 3,513,429
"Heat Recoverable Actuator"
W. R. Helsop, Assignor to Raychem Corp.
Filed 30 Oct 1968
Issued 19 May 1970
22 Claims (Cl. 337-382)

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R. G. Cooper
Filed 9 Jun 1967
Issued 2 Jun 1970
6 Claims (Cl. 340-227.1)

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W. J. Buehler, Assignor to U.S.A.
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19 Claims (Cl. 75-135)

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Filed 12 Jun 1969
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D. L. Watrous and J. D. Harnden, Assignors to General Electric Co.
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Issued 1 Jun 1971
2 Claims (Cl. 337-382)

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F. E. Wang, Assignor to U.S.A.
Filed 26 Feb 1968
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6 Claims (Cl. 148-13)

Patent No. 3,594,674
"Temperature-Responsive Control Devices Adjustably Responsive to Various Operating Temperatures"
J. R. Willson, Assignor to Robertshaw Controls Co.
Filed 13 Aug 1969
Issued 20 Jul 1971
25 Claims (Cl. 337-139)

Patent No. 3,594,675
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J. R. Willson, Assignor to the Robertshaw Controls Co.
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Issued 20 Jul 1971
9 Claims (Cl. 337-140)

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J. R. Willson, K. T. Krueger, H. J. Tyler and W. F. Jackson, Assignors to Robertshaw Controls Co.
Filed 17 Jul 1969
Issued 19 Oct 1971
62 Claims (Cl. 137-625.44)

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R. D. Fannon, B. R. Lower and L. E. Laufe, Assignors to L. E. Laufe
File 15 Jun 1970
Issued 16 Nov 1971
8 Claims (Cl. 128-130)

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"Temperature-Responsive Switch Assemblies"
J. R. Willson, K. T. Kreuger, H. J. Taylor and W. F. Jackson, Assignors to Robertshaw Controls Co.
Filed 22 Jul 1969
Issued 11 Jan 1972
28 Claims (Cl. 337-123)

Patent No. 3,645,443
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J. R. Willson and K. T. Krueger, Assignors to Robertshaw Controls Co.
Filed 19 Dec 1969
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9 Claims (Cl. 236-34)

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J. R. Willson and D. W. Carey, Assignors to Robertshaw Controls Co.
Filed 27 May 1969
Issued 28 Mar 1972
10 Claims (Cl. 337-140)

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A. Negishi, K. Takayanagi and M. Ikeda, Assignors to the Furukawa Electric Co., Ltd, Tokyo, Japan
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16 Claims (Cl. 75-134)

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W. F. Jackson and J. R. Willson, Assignors to Robertshaw Controls Co.
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Issued 23 May 1972
20 Claims (Cl. 236-93)

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W. J. Buehler
Filed 4 Nov 1966
Issued 27 Jun 1972
1 Claim (Cl. 75-170)

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G. A. DuRocher, Assignor to Essex International, Inc.
Filed 28 Jul 1969
Issued 11 Jul 1972
17 Claims (Cl. 337-140)

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W. J. Buehler, Assignor to the U.S.A.
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8 Claims (Cl. 75-10)

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H. J. Tyler, Assignor to Robertshaw Controls Co.
Filed 2 Jul 1969
Issued 15 Aug 1972
10 Claims (Cl. 337-140)

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H. J. Taylor, Assignor to Robertshaw Controls Co.
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Issued 12 Sep 1972
3 Claims (Cl. 337-123)

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"Titanium-Nickel Alloy Manufacturing Methods"
S. Abkowitz, J. M. Siergiej and R. R. Regan, Assignors to S. Abkowitz
Filed 21 Apr 1969
Issued 24 Oct 1972
7 Claims (Cl. 75-170)

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R. N. Levinn, Assignor to American Thermostat Corp.
Filed 1 Apr 1971
Issued 21 Nov 1972
3 Claims (Cl. 337-140)

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G. A. DuRocher, Assignor to Essex Internationsl Inc.
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17 Claims (Cl. 337-139)

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Issued 3 Apr 1973
13 Claims (Cl. 337-140)

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R. N. Levinn, Assignor to American Thermostat Corp.
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Issued 1 May 1973
9 Claims (Cl. 337-140)

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R. F. Otte and C. L. Fischer, Assignors to Raychem Corp.
Filed 29 Jun 1971
Issued 26 Jun 1973
16 Claims (Cl. 29-628)

Patent No. 3,748,197
"Method for Stabilizing and Employing Temperature Sensitive
Material Exhibiting Martensitic Transitions"
J. R. Willson and D. W. Carey, Assignors to Robertshaw Controls Co.
Filed 14 Sep 1971
Issued 24 Jul 1973
7 Claims (Cl. 148-131)

Patent No. 3,753,700
"Heat Recoverable Alloy"
J. D. Harrison, J. Y. Choi and P. R. Marchant, Assignors to Raychem Corp.
Filed 2 Jul 1970
Issued 21 Aug 1973
2 Claims (Cl. 75-134)

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"Method of Achieving Thermally Balanced Hot Wire Relay Type Devices"
H. J. Tyler, Assignor to Robertshaw Controls Company
Filed 9 Dec 1971
Issued 21 Aug 1973
10 Claims (Cl. 148-13)

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R. Levinsohn and J. E. Jervis, Assignors to Raychem Corp.
Filed 8 Sep 1970
Issued 18 Sep 1973
13 Claims (Cl. 285-175)

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R. F. Otte, Assignor to Raychem Corp.
Filed 21 Jun 1972
Issued 1 Jan 1974
12 claims (Cl. 337-393)

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Mark Page and Phillip N. Sawyer
Filed 16 Jul 1971
Issued 6 Aug 1974
11 Claims (Cl. 128-1D)

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W. J. Buehler
Filed 1 May 1972
Issued 8 Oct 1974
8 Claims (Cl. 73-67.1)

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C. D. Hickling, Assignor to American Thermostat Corp.
Filed 14 Jun 1973
Issued 19 Nov 1973
10 Claims (Cl. 337-382)

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"Article and Method for Locating Contacts"
R. F. Otte, Assignor to Raychem Corp.
Filed 4 Apr 1975
Issued 21 Jan 1975
13 Claims (Cl. 29-626)

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"Relay"
D. E. Clarke, Assignor to Texas Instruments Inc.
Filed 16 Apr 1973
Issued 18 Mar 1975
7 Claims (Cl. 337-140)

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P. E. Nichols and C. L. Martin, Assignors to Raychem Corp.
Filed 19 Dec 1973
Issued 25 Mar 1975
17 Claims (Cl. 29-447)

Patent No. 3,905,228
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